



Cost, effort and outcome of mammal rediscovery: Neglect of small species

Diana O. Fisher*

The University of Queensland, School of Biological Sciences, St. Lucia, 4072 Queensland, Australia

ARTICLE INFO

Article history:

Received 3 January 2011

Received in revised form 2 March 2011

Accepted 8 March 2011

Available online 1 April 2011

Keywords:

Rediscovery

Mammal extinction

Recovery plan

Body size

Captive breeding

ABSTRACT

There is often intense public interest in the process of rediscovery of species that were presumed extinct, although rediscovered mammals are typically small, inconspicuous inhabitants of tropical forests. Conservation actions for small species are relatively inexpensive compared to the interventions required to protect charismatic, large mammals. However, threatened small mammals such as rodents, bats, shrews and small marsupials attract less research attention, conservation actions, space in zoos, and funding than larger species, and most threatened small mammals receive no attention, particularly those in tropical forest habitats. I investigated how the body size of rediscovered mammals has changed during the last century, how body size is associated with search and conservation effort and subsequent recovery, and the success of recovery actions for rediscovered mammals. There has been a strong decline in the mean body size of rediscovered mammals since the 19th century. Smaller species were missing for longer before rediscovery, and attracted less search effort. Cost estimates were lower in recovery plans for smaller rediscovered mammals. Despite this, increasing population trend after rediscovery was associated with larger body size, and larger species recovered better with conservation effort, although small species declined despite conservation effort. All species with no conservation actions (the majority of small species) were declining. Sixty percent of rediscovered mammals remain critically endangered or endangered, and 8% (6 species) are likely to be extinct. I argue that conservation outcomes for rediscovered mammals could be greatly improved by a modest increase in attention to small-bodied species.

© 2011 Elsevier Ltd. All rights reserved.

1. Introduction

More than a third of mammal species that have been classified as extinct, possibly extinct, or flagged as missing, have been rediscovered. These rediscovered mammals were all last recorded between the 1820s and the present (Fisher and Blomberg, 2011). Many missing species have a high scientific or public profile (Roberts et al., 2010; Scott et al., 2008), although the majority of rediscovered mammals are inconspicuous (Fisher, 2010; Fisher and Blomberg, 2011). Fisher and Blomberg (2011) analyzed data on rediscovery rates of purportedly extinct mammals since 1500, to determine which traits affect the probability of rediscovery. They found that body size did not independently predict rediscovery rate, although persecuted and harvested species are predominantly large and conspicuous (Fisher and Owens, 2004; Isaac and Cowlshaw, 2004; Owens and Bennett, 2000), and these tended to be rediscovered more frequently in the 20th century (Fisher and Blomberg, 2011). Mammals that declined due to habitat loss were also rediscovered relatively frequently, unless they had very restricted ranges. Species affected by habitat loss are most likely

to be small-bodied endemics, especially in tropical forests (Bennett and Owens, 2002; Fisher, 2010; Fisher and Owens, 2004; Owens and Bennett, 2000). Fisher and Blomberg (2011) showed that a few charismatic, large, missing mammals have been the focus of disproportionately high, but unsuccessful search effort, but most missing mammals received little or no attention.

We might expect that this lack of attention would be reflected in lower search effort, a longer time to be rediscovered, less funding for searches, fewer conservation actions and therefore a relatively poor chance of recovery of uncharismatic species after rediscovery, because there is substantial published evidence of bias in favor of large species conservation. Amori and Gippoliti (2000) found that globally, rodents, bats, insectivores, and most small marsupials were severely under-represented in published single-species conservation studies of mammals, relative to the proportion of threatened species in these orders. The proportion of threatened insectivores, microchiropterans and rodents in captive breeding programs is tiny ($\leq 1\%$), in contrast to large-bodied groups such as primates, carnivores and ungulates (Balmford et al., 1996). Sitas et al. (2009) concluded that 75% of threatened mammals receive no conservation actions, and that the orders Insectivora, Didelphimorphia (South American marsupials), Rodentia and Chiroptera have the least conservation effort. Small rodents, bats, shrews and marsupials typically use cryptic behavior to avoid predators, are nocturnal, often solitary and arboreal, and can only

* Address: School of Biological Sciences, Goddard Building (8), The University of Queensland, St. Lucia, 4072 Queensland, Australia. Tel.: +61 7 33469004; fax: +61 7 33651655.

E-mail address: d.fisher@uq.edu.au

be observed by specialist trapping methods (Sutherland, 2003). Such mammals have a low public profile (Sitas et al., 2009), and species identification often requires expert knowledge, so fewer potential searchers are able to recognise them. Conversely, large mammals attract the most public interest, research attention, representation on Species Survival Commission specialist groups, and conservation funding (Amori and Gippoliti, 2000; Gimenez-Dixon and Stuart, 1993; Magin et al., 1994; Metrick and Weitzman, 1996; Sitas et al., 2009; Ward et al., 1998). Gimenez-Dixon and Stuart (1993) found that in the 10 years after the development of the first Species Survival Commission action plans, more projects suggested in action plans were implemented for taxonomic groups containing large species (e.g. elephants: 156 projects, cetaceans: 24 projects, mustelids and viverrids (small-bodied carnivorous mammals): six projects). Large mammals were the most likely taxa to be listed by the US Endangered Species Act in the early 1990s (Metrick and Weitzman, 1996). Recently, Sitas et al. (2009) showed that large-bodied, well-known and charismatic mammals still receive the majority of conservation actions globally. Metrick and Weitzman (1996) found that body size and taxonomic group were the main determinants of conservation spending in the USA. Large species and mammals were favored. The authors interpreted this to mean that conservation attention was focused on species that are most attractive to us, because they most resemble humans. In agreement with the idea that large species are valued disproportionately by conservation managers, Balmford et al. (1996) found that zoos prioritize exhibition and breeding of large vertebrates, although threatened species far outnumber the space and resources available for captive breeding. Attractiveness and body size are also the main determinants of the size of other captive vertebrate populations (the number of individuals in captivity), such as snakes (Marešová and Frynta, 2008).

Balmford et al. (1996) suggested that bias towards large species results in inefficient use of conservation resources, because small-bodied taxa are more likely to breed well in captivity, and are cheaper to maintain in appropriate numbers for genetic management. Larger carnivores are more likely to show abnormal behavior and signs of stress in captivity (Clubb and Mason, 2003), and breeding programs for the smallest mammals cost around a tenth of those for the largest (Balmford et al., 1996). Small mammals in tropical regions are least likely to receive conservation attention, and most receive none (Sitas et al., 2009), despite conservation actions such as habitat protection being cheapest to implement in these regions (Balmford et al., 2003), and the smaller area of habitat required by small species (Fisher and Owens, 2004). Reduced spending on conservation measures presumably increases extinction risk (Brooks et al., 2009; Joseph et al., 2009), and this effect is expected to be acute in newly-rediscovered species, which are by definition very close to extinction. Lack of interest in rediscovered small mammals is therefore predicted to lead to continued decline and rapid extinction of many of these species. In this paper, I investigate how and why mean body size of rediscovered mammals has changed over time, how body size has influenced the effort devoted to rediscovery and subsequent recovery of missing mammals, and the success of recovery efforts. I interpret conservation outcomes in the context of searcher expertise and funding.

2. Methods

2.1. Data and definitions

I compiled a global database of species that have published accounts of rediscovery or attempted rediscovery (see Fisher and Blomberg, 2011). I established the status and detection history of

these species using past and present IUCN red lists and related publications, primary literature, books, and the Committee on Recently Extinct Organisms mammal database (MacPhee and Flemming, 1999). I obtained population trend data (ranked -1 for declining, 0 for stable, and 1 for increasing), conservation status categories, and recovery actions from the present IUCN red list and published species recovery plans. I ranked recovery actions as follows: the species occurs in a minimally-managed or unmanaged reserve = 1, an actively managed reserve = 2, captive breeding = 2, translocation = 2, and listing/legal protection only = 0. I summed the action ranks for each species to obtain an index of recovery effort. I determined the identity of searchers and their institutions from these publications, and from accounts in Bille (1995, 2006) and Shuker (1993). I assigned a searcher institution/profession in 13 categories: museum researcher, zoo employee, amateur naturalist, professional scientific society, farmer, environmental consultant, construction worker, government agency, university faculty, postgraduate student, wildlife photographer, hunter, or non-government conservation organization.

I determined sources of funding for searches from the acknowledgements sections of papers, and divided these into nine categories: self-funded, museum, zoo, amateur natural history society, government agency, university, private industry, grant funding body, or non-government conservation organization. I contacted individual searchers directly to obtain estimates of the cost of mounting particular search expeditions (except in the case of the kouprey *Bos sauveli*, which had search cost estimates included in a recovery plan). The total cost of expeditions did not include salary. I determined the estimated cost of species recovery for 5 years from the most recent available published species recovery plans which included detailed costings. I converted currency to US dollars by using contemporary exchange rates, then converted between years to account for inflation using a US gross domestic product deflator index based on the International Monetary Fund (2010). For each species, I recorded body mass (g), and traits likely to be associated with body mass: the threat associated most with decline, and ranked geographic range size. A main threat was assigned if one threat was reported to be the major one, either habitat loss (deforestation, agricultural clearing, fragmentation, degradation, overgrazing), overkill (harvesting, hunting, exploitation, persecution or bycatch) or introduced species (invasive predators or diseases). I recorded geographic range rank (range with a precision of one order of magnitude; 1 = up to 1 km², 2 = 1–10 km², 7 = 100,000–1000,000 km²) (Fisher and Blomberg, 2011).

For rediscovered species, the index of search effort was the number of reported search expeditions targeted to the species after it was reported missing, and before it was rediscovered. I also used the number of searches targeted to species that remain missing or extinct after their last sighting, in order to test for a correlation between search effort and body size (data from Fisher and Blomberg, 2011).

2.2. Statistical analysis

I used linear models in R (R Development Core Team, 2010) to test for associations between the date of rediscovery and (log) body mass; last sighting date and (log) body mass; the interval between last sighting date and rediscovery and (log) body mass; search effort and (log) body mass of missing species; search cost and (log) body mass, (log) former range size, distance between the home institution of the searcher and the rediscovery site, and local versus overseas location of searchers; estimated cost of recovery and (log) body mass, threat, (log) former range size, the interval between last sighting date and rediscovery, or discovery/species description date; the index of recovery effort and (log) body mass, population trend versus (log) body mass and index of recovery effort. I used an anova in R

to test if mean rediscovery date varied according to the profession of rediscoverers, and separate anovas to test if mean rediscovery date varied with funding source, and to test if mean (log) body mass varied with profession of rediscoverers or funding body. I used Tukey HSD post hoc tests to determine where significant differences were in these overall models. Because multiple searchers usually contributed to the rediscovery of each species, and multiple funding bodies supported each rediscovery, each species could be represented more than once in this analysis.

I did not use statistical models to account for phylogenetic non-independence, because previous analyses of this dataset have shown that phylogenetic signal in the traits associated with rediscovery (including body mass) is very weak or non-existent. In previous analyses, there was no significant difference between any of the phylogenetic and non-phylogenetic linear model results ($P > 0.99$ in each case). This is probably because rediscoveries are scattered across families and genera of mammals, rather than being clumped in certain phylogenetic lineages (Fisher, 2010; Fisher and Blomberg, 2011).

3. Results

During the last century, there has been a strong, progressive decline in the mean body size of rediscovered mammals ($F_{1,60} = 11$, $p = 0.001$). This is not due to an increase in the proportion of rediscovered species affected by habitat loss relative to the number of species affected by overkill; there was no significant change in the mean category of threat affecting mammals that are rediscovered (overall model with date as the dependent variable, and logged species body mass and threat type as interacting independent variables, $F_{5,60} = 3.4$, $p = 0.009$), and no interaction between threat and body size in this model (Fig. 1). The change in body size of rediscovered mammals was not a reflection of any decline in the mean body size of presumed-extinct species since 1820 (the pool of species from which rediscoveries are made); there was no significant association between the last sighting date of extinct mammals since 1820 and body mass ($F_{1,73} = 0.9$, $p = 0.35$). Larger

species were also missing for significantly shorter periods of time before rediscovery ($F_{1,64} = 5.7$, $p = 0.02$). Missing mammals have predominantly been rediscovered by museum researchers and university academics (Fig. 2a). Together, these two professions account for nearly half of all people making mammal rediscoveries globally (45/99 searchers). A substantial number of missing species have also been found by employees of government environment departments, non-government conservation organizations (NGOs) and amateur natural historians. Only 10% of people involved in mammal rediscoveries were not in a profession that requires biological training (two construction workers in a National Park, three wildlife photographers, one hunter, and four farmers). There has been no obvious change in the level of expertise of searchers, but there has been a change in the relative roles of museum researchers and university academics in mammal species rediscovery during the last century. The mean date of rediscovery for species found by museum employees (the late 1960s) is earlier than the mean date of species found by university academics and conservation NGOs (the 1990s) (Fig. 2a, $F_{12,86} = 2.2$, $p = 0.018$, Tukey post hoc test: difference between academics and museums, $p = 0.03$, difference between NGOs and museums, $p = 0.03$). Rediscovery of missing mammals has predominantly been funded by museums, non-government conservation organizations, and government departments, which together account for 47% of funding sources (Fig. 2b). A substantial minority of rediscoveries (15%) have also been entirely self-funded by individuals. There has been a trend towards greater funding by NGO's, charities and private industry from the late 1980s to the present, with fewer rediscoveries tending to be self-funded by individuals, or funded by museums than in the 1960s and 70s. ($F_{8,93} = 2.4$, $p = 0.02$, Tukey post hoc test: difference between NGOs and self, $p = 0.06$, difference between NGOs and museums, $p = 0.015$). Although the profession of searchers and the sources of funding have changed during the last century, this did not explain why mean body mass of rediscovered species has declined. Searcher profession and funding source were not associated with mean body mass of rediscovered species ($F_{12,86} = 0.6$, $p = 0.86$ and $F_{8,93} = 1.5$, $p = 0.17$, respectively). Species

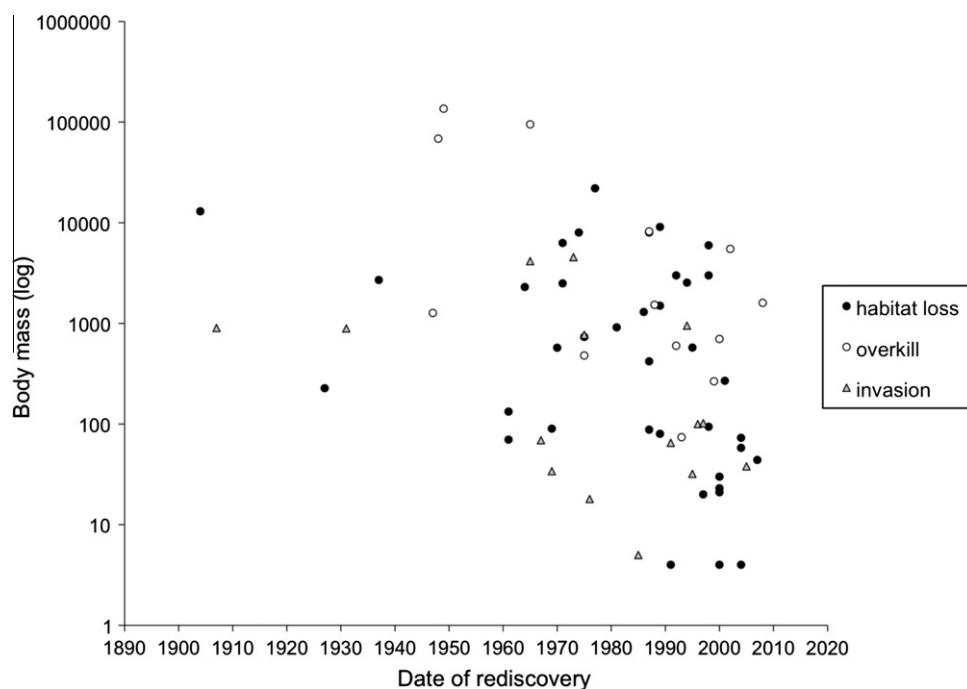


Fig. 1. Decline in body mass in rediscovered mammals between 1900 and 2010, with respect to threats.

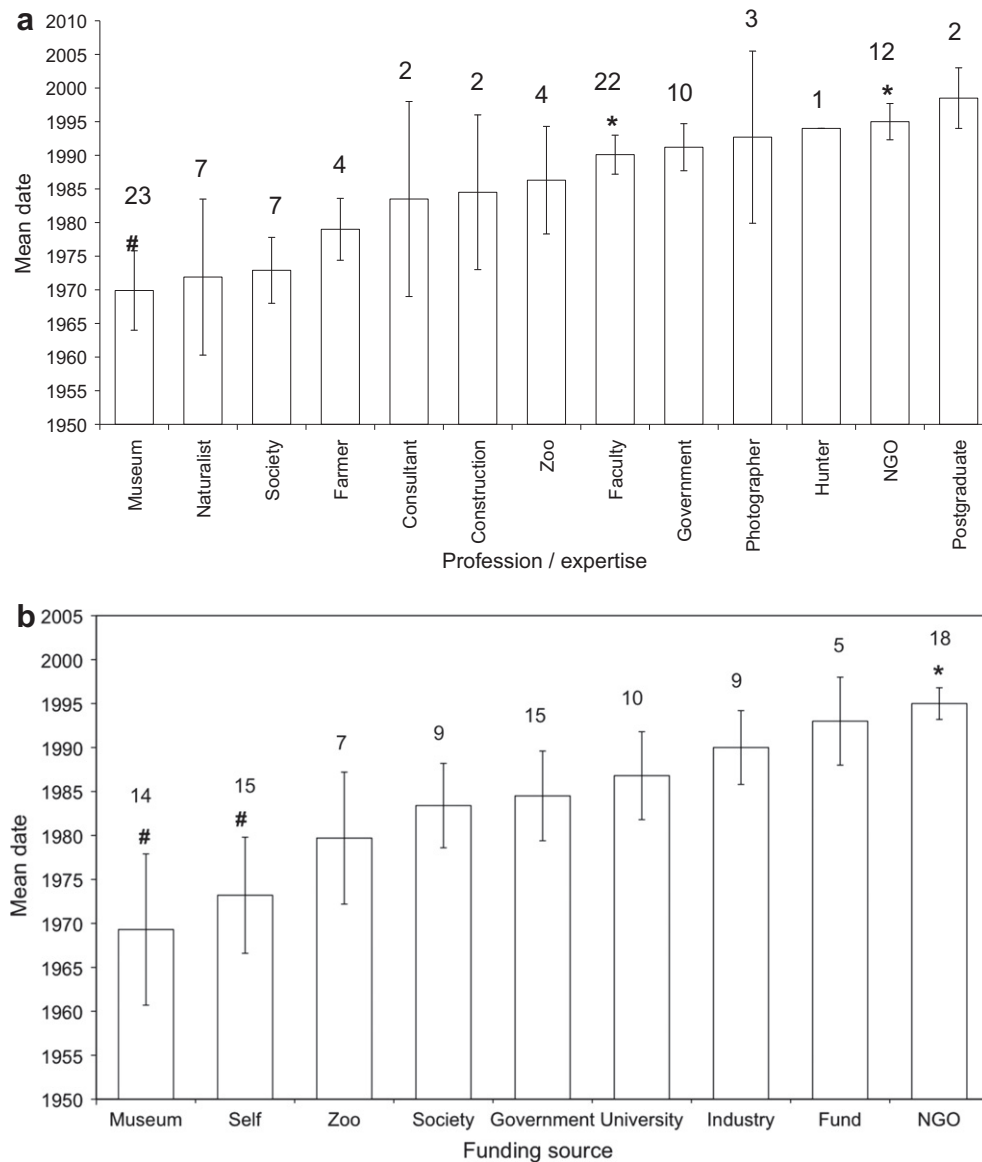


Fig. 2. Changes in the relative contribution of categories of profession involved in making and funding rediscoveries of 67 mammals between 1900 and 2010. Error bars are standard errors. Sample sizes (number of searchers/funders) are shown above each category of profession. The number of searchers and funders is more than the number of species, because some species were searched for by expeditions with multiple people, or more than one funding body contributed to the funding. Means with a * differ significantly from those with a # (overall models $p < 0.10$). Means with the same symbol do not differ significantly from one another. (a) rediscoverers and (b) funders. Industries are mining companies (four species), fishing (one species), airlines (two species), tea (one species) and tobacco (one species).

rediscovered by museum employees weighed 9131 ± 4897 g, and those rediscovered by university researchers weighed 7627 ± 6138 g.

We were able to obtain an estimate of the cost of searching for 15 species that have been targeted by expeditions aiming to rediscover them since 1980 (around a quarter of the number of rediscovered species). These were: the Talaud flying fox *Acerodon humilis* (successful search), kouprey *B. sauveli* (unsuccessful search), Christmas Island shrew *Crociodura trichura* (unsuccessful search), Machu Pichu chinchilla rat *Cuscomys oblativa* (unsuccessful search), woolly flying squirrel *Eupetaurus cinereus* (successful search), Salim Ali's fruit bat *Latidens salimali* (successful search), dibbler *Parantechinus apicalis* (successful search), Puebla deer mouse *Peromyscus mekisturus* (unsuccessful search), Bahian tree rat *Phyllomys unicolor* (successful search), Bougainville monkey-faced bat *Pteralopex anceps* (successful search), Julia Creek dunnart *Sminthopsis douglasi* (successful search), pygmy tarsier *Tarsius*

pumilus (unsuccessful search), Attenborough's echidna *Zaglossus attenboroughi* (unsuccessful search), and central rock rat *Zyomys pedunculatus* (unsuccessful search). The mean cost for three people to search for 12 weeks (the mean effort, rounded to whole numbers) did not depend on the body size of the target species, or its former range size, or the distance between the home institution of the searcher and the rediscovery site. However, the cost of a 12 week search if the expedition organisers lived locally (in the same country as the target species) was less than a third as much as expeditions whose leaders travelled from another country to search ($\$8970 \pm 3216$ versus $\$33,707 \pm 6429$, $t = 2.6$, $p = 0.03$, overall model $F_{2,12} = 5.3$, $p = 0.02$, $r = 0.62$). We also repeated the analysis using raw costs, not adjusted for inflation. The conclusions were unchanged (non-adjusted costs for the same country: $\$8696 \pm 3285$ versus another country: $\$32,541 \pm 6454$). The amount spent (taking the search duration for individual species into account), also did not depend on the body size of the target

species, or its former range size, or the distance between the home institution of the searcher and the rediscovery site. Searchers who lived locally spent around 75% less (\$5596 ± 1780 versus \$27,707 ± 4650, overall model $F_{1,13} = 17.7$, $p = 0.001$, $r = 0.73$).

Most rediscovered species either had no recovery plans (that I was able to locate), or had plans with no costings. I obtained the estimated cost of recovery for 5 years from published recovery plans for rediscovered species ($n = 13$, the bridled nailtail wallaby *Onychogalea fraenata*, northern hairy-nosed wombat *Lasiorhinus krefftii*, Leadbeater's possum *Gymnobelideus leadbeateri*, Gilbert's potoroo *Potorous gilberti*, Pygmy hog *Porcula salvania*, Heath mouse *Pseudomys shortridgei*, Sandhill dunnart *Sminthopsis psammophila*, dibbler *Parantechinus apicalis*, Hastings River mouse *Pseudomys oralis*, Cuvier's hutia *Plagiodontia aedium*, Julia Creek dunnart *S. douglasi*, Hispaniolan Solenodon *Solenodon paradoxus*, and black-footed ferret *Mustela nigripes*) and two missing/extinct species; the baiji, *Lipotes vexillifer* (which had a costed recovery plan prepared in case of rediscovery, but was not rediscovered), and the red wolf, *Canis rufus* (which is extinct in the wild and has a costed recovery plan). For these 15 species, cost of recovery for 5 years was not significantly correlated with threat, former range size, the interval between last sighting date and rediscovery, or discovery date, but it was significantly associated with body mass ($F_{2,10} = 8.6$, $p = 0.015$, $r = 0.59$, Fig. 3). The mean estimate of recovery cost over 5 years for small rodents, shrews, and small marsupials (<1000 g) was approximately half a million dollars (US\$ 496,414 ± 168,427). The mean cost for medium-sized species (Gilbert's potoroo *P. gilberti*, the pygmy hog *P. salvania*, and Leadbeater's possum *G. leadbeateri*) was approximately a million dollars (US\$ 11,75,133 ± 919,558). Larger species (excluding one outlier, see below) cost around three million (US\$ 29,05,455 ± 649,213). The outlier was the black-footed ferret *M. nigripes* (a US species at the low end of the medium body size category, approximately one kilogram), which had an estimated cost of recovery of around eleven million dollars for a 5-year recovery plan. The species with the second highest estimate of recovery cost, the red wolf, is also a North American mammal. Thus, a typical search using overseas agencies to rediscover a large-bodied mammal species cost on average ~2% of the total estimated cost of recovery for 5 years, and ~7% of the total cost of recovery for small-bodied species (e.g. rodents < 1000 g).

Around a third of missing and extinct species have not been the targets of any documented searches, and a quarter of rediscovered species have had no conservation actions applied to them (apart from listing). Most rediscovered mammals (80%, not including Data Deficient species) are declining. Few are stable (6%), or increasing (6%). Six rediscovered species are now listed as EX or CR (tagged as possibly EX) (8% of rediscoveries, Fig. 4). These are the desert rat kangaroo *Caloprymnus campestris*, central rock rat *Z. pedunculatus*, Garrido's hutia *Mysateles garridoi*, King rat *Uromys rex*, Christmas Island shrew *C. trichura*, and Vanikoro flying fox *Pteropus tuberculatus*. The desert rat kangaroo and central rock rat are Australian desert mammals, and the others are tropical island dwellers. All of these species are relatively small-bodied (4–1600 g). The central rock rat survives in two captive populations, and conservation actions including captive breeding and habitat protection are underway. The only known individual of the Christmas Island shrew was briefly kept in captivity for 12 months after its rediscovery. A second individual died shortly after capture, therefore no meaningful management, such as captive breeding, was possible. There were no conservation actions attempted after the rediscovery of the other extinct (and possibly extinct) rediscovered species. Not including EX and CR (possibly EX) species, 60% of rediscovered mammals are critically endangered or endangered. A small minority (12%) are now 'near threatened' or 'least concern', nearly all because of a change in knowledge about their status. The three rediscovered species classified as increasing in population size by the IUCN are two fur seals that were harvested to near-extinction and have now substantially recovered since the complete cessation of hunting (the Juan Fernández and the Guadalupe fur seal, *Arctocephalus philippii* and *A. townsendi*), and the black-footed ferret *M. nigripes* (the target of extraordinary recovery funding and effort). The index of search effort for missing species (the number of searches documented in published reports) was significantly but weakly correlated with body mass ($F_{1,185} = 9.8$, $p = 0.002$, $r = 0.22$). The index of recovery effort for rediscovered species was not associated with body mass ($F_{1,65} = 1.0$, $p = 0.32$). However, increasing population trend after rediscovery was associated with increasing body mass ($F_{1,54} = 9.1$, $p = 0.004$), more conservation actions taken after rediscovery (recovery effort) ($F_{1,54} = 15.1$, $p = 0.0003$), and an interaction between body mass and actions: smaller species declined regardless of the number of

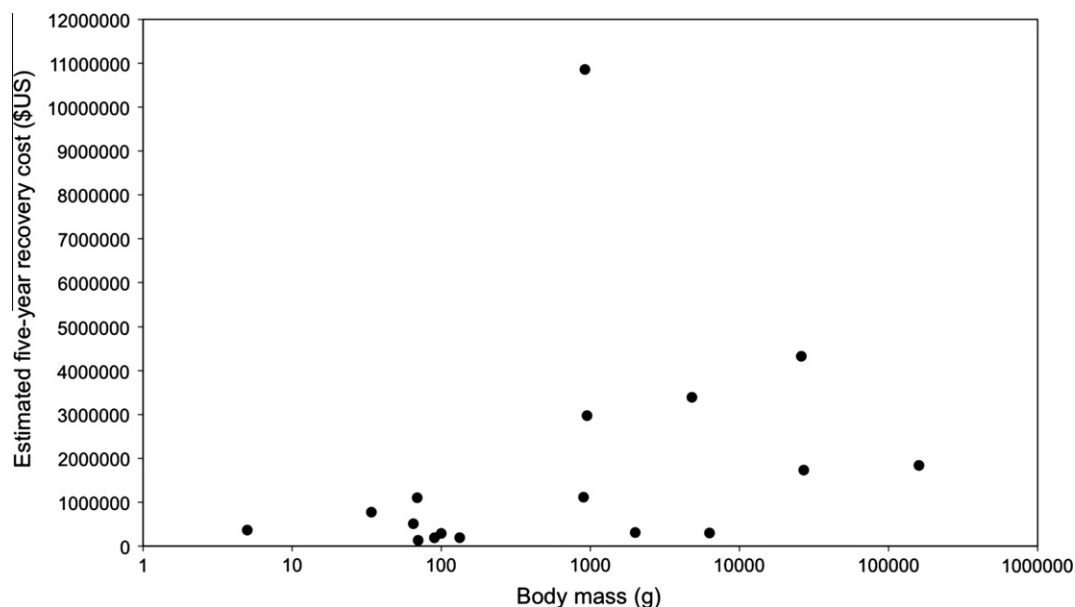


Fig. 3. Estimated cost to implement a 5-year recovery plan versus body mass of rediscovered species. The outlier (\$11 M) is the black-footed ferret, *Mustela nigripes*.

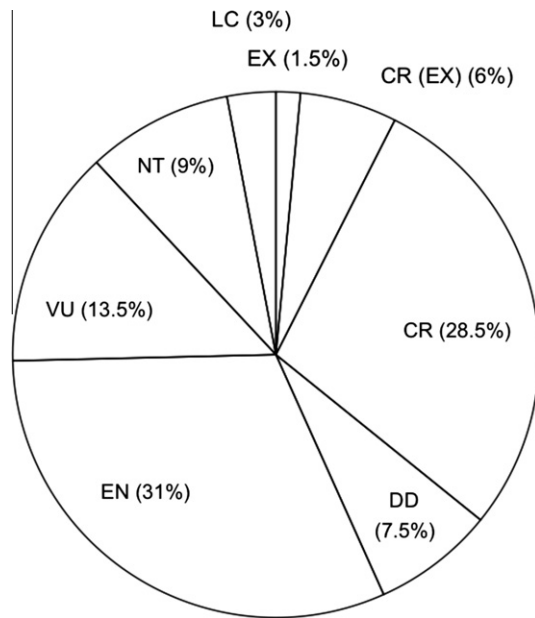


Fig. 4. IUCN red list status of rediscovered mammals. EX = extinct, CR (EX) = critically endangered, tagged as possibly extinct, CR = critically endangered, EN = endangered, VU = vulnerable, NT = near-threatened, LC = least concern, DD = data-deficient.

conservation actions, and larger species increased in population size more if they had more conservation actions ($F_{1,54} = 6.6$, $p = 0.01$). Population trend after rediscovery was not associated with threat or former range size.

4. Discussion

If small missing mammals do receive less conservation attention than large species, we expected the rediscovery of extant species to be delayed, relative to larger species. We also expected that small species would receive lower search effort, less funding for searches, and fewer conservation actions after rediscovery than large mammals. Most of these expectations were upheld. The striking decline in mean body size of rediscovered species since the 19th century, and the longer interval between last sighting date and rediscovery date in smaller mammals, are consistent with less attention to smaller species by searchers, and also with elusiveness of small species. Fisher and Blomberg (2011) found that moderate search effort increased the probability of rediscovery in missing mammals, independently of other significant predictors such as the cause of decline. Therefore, the lower search effort for smaller mammals is consistent with the idea that lack of attention is related to the decline in body size of rediscovered species over time. The body size of rediscovered species was an increasingly biased subset of the body size distribution of missing mammals during the last century, because there was no change in the body size distribution of the source pool of species from which rediscoveries were made during this time (missing and extinct mammals since 1820). The declining body size of rediscovered species parallels the pattern of declining body size in new species descriptions during the last century. For example, Medellín and Soberón (1999) extrapolated the relationship between description rate, taxonomy and species characteristics to conclude that most mammals remaining to be rediscovered will be rodents, insectivores and bats under 100 g, and Collen et al. (2004) found that recently described carnivores and primates are small-bodied, with small geographic ranges. Most species recently described and remaining to be

discovered are from tropical forest areas of high endemism in Asia, South America, Oceania and Africa, and are likely to be threatened by habitat loss because of their small ranges (Reeder et al., 2007). Tropical forests are also the most likely habitats in which to rediscover missing mammals in the future (Fisher, 2010; Fisher and Blomberg, 2011), supporting the recent conclusions of Sitas et al. (2009), that tropical forests are the most neglected areas globally in terms of small mammal conservation attention.

Search costs for missing mammals were cheap. Several respondents commented that their expeditions were particularly inexpensive, because they made a special effort to keep costs low (e.g. by camping, and using the cheapest transport and food. For example, Mittermeier et al. (1977) noted in their methods that they took local buses to travel to the rediscovery site in Peru). Although few rediscoveries were funded entirely by individuals (especially recently, with the greater availability of NGO funding than in the early 20th century), most were probably subsidised by individuals, masking their true cost.

Attention given to missing mammals at the searching stage did not appear to vary with searcher profession or expertise. We found no evidence that rediscoveries in the early twentieth century were made and funded by professions and groups that were more motivated to seek out large, charismatic mammals than now. The reduction in mean body size of rediscovered mammals has occurred despite the relative decline in the contribution of museum taxonomists to making and funding rediscoveries, and greater funding contribution from NGOs, charities and private companies. The mean body size of rediscovered species did not differ between searcher professions or funding sources. This implies that bias towards large species in conservation attention given to mammals occurs across a range of professions, including specialist researchers and taxonomists. Search costs did not depend on body size, but were much less if the searcher's institution was in the same country as the rediscovery site. Cost efficiency seemed to be increased by familiarity rather than decreased by travel distance, for example, some searchers in Australia and Brazil traveled very long distances, but expeditions were still much cheaper than those of overseas searchers.

Once rediscovered, mean estimates of the cost of recovery for small species were a quarter of that for larger mammals. This is probably partly because activities such as captive maintenance cost less per individual for species with short generation times and decreased space requirements, and small species usually need less intensive intervention to breed well in captivity (Balmford et al., 1996). It might also be because authors of recovery plans underestimate the amount of money required for effective conservation. They might ask for less because they are pre-empting likely funding decisions, given that a greater share of finite funding is unlikely to be allocated to small species at the expense of more charismatic mammals (Joseph et al., 2009; Metrick and Weitzman, 1996). The finding that smaller species were more likely to show a declining population trend after rediscovery, and larger species benefited disproportionately from greater conservation efforts suggests that recovery effort allocated to rediscovered small mammals has often been inadequate. Rediscovered small mammals were more likely to decline, despite the fact that global analyses have repeatedly shown large body size to be a strong predictor of extinction risk and population loss in mammals (Cardillo et al., 2005; Davidson et al., 2009; Fisher and Owens, 2004).

Although most rediscovered species are declining, very few have become extinct. In agreement with the conclusions of Brooks et al. (2009) and Rodrigues (2006), my results show that spending and effort on conservation actions do make a significant difference to the prospects of recovery. The index of recovery effort applied to individual species was strongly correlated with their population trend after rediscovery. All species with no actions were

categorized as declining, but no actively-managed rediscovered species subsequently became globally extinct. The rediscovered mammal with the greatest financial investment, according to its recovery plan (the black-footed ferret) is one of only three with an increasing population trend. This suggests that North American species in the dataset were at the upper end of the funding distribution because their recovery cost estimates were adequate. Searching for missing mammals is inexpensive, especially if done by local expeditions, and is often funded by non-government sources which do not compete with other aspects of recovery planning, such as captive breeding. Recovery actions for rediscovered small mammals appear to be generally either lacking or underfunded, although they are relatively inexpensive to implement. I conclude that there is a strong potential to improve conservation outcomes for rediscovered mammals with only a modest re-allocation of resources to include more small species.

Acknowledgments

I thank Peter Baxter for useful comments on the manuscript. I am extremely grateful to the following who generously responded to my questions about the cost of searching, and the status of costed recovery plans, and provided valuable discussion and ideas: Alan Horsup, Berry Mulligan, Brent Sewall, Chris Pavey, Chris Walzer, Claudio Valladares- Padua, Craig Turner, Evan Bowen-Jones, Fernando Cervantes, Ignacio De la Riva, Jeremy Bird, Jon Riley, Jonathan Baillie, Lawrence Heaney, Louise Emmons, Luis Darcy Verde Arregoitia, Nikki Hammond, Pablo Tete, Pat Woolley, Paul Meek, Peter Zahler, Petra Kaczensky, Robert Dowler, Samuel Turvey, Sharon Gursky, and Yuri Leite. This work was supported by an Australian Research Council Fellowship.

References

- Amori, G., Gippoliti, S., 2000. What do mammalogists want to save? Ten years of mammalian conservation biology. *Biodiversity and Conservation* 9, 785–793.
- Balmford, A., Mace, G.M., LeaderWilliams, N., 1996. Designing the ark: setting priorities for captive breeding. *Conservation Biology* 10, 719–727.
- Balmford, A., Gaston, K.J., Blyth, S., James, A., Kapos, V., 2003. Global variation in terrestrial conservation costs, conservation benefits, and unmet conservation needs. *Proceedings of the National Academy of Sciences United States of America* 100, 1046–1050.
- Bennett, P.M., Owens, I.P.F., 2002. *Evolutionary Ecology of Birds: Life History, Mating System and Extinction*. Oxford University Press, Oxford, UK.
- Bille, M., 1995. *Rumors of Existence: Newly Discovered, Supposedly Extinct, and Unconfirmed Inhabitants of the Animal Kingdom*. Hancock House, Blaine, WA, USA.
- Bille, M., 2006. *Shadows of Existence: Discoveries and Speculations in Zoology*. Hancock House, Blaine, WA, USA.
- Brooks, T.M., Wright, S.J., Sheil, D., 2009. Evaluating the success of conservation actions in safeguarding tropical forest biodiversity. *Conservation Biology* 23, 1448–1457.
- Cardillo, M., Mace, G.M., Jones, K.E., Bielby, J., Bininda-Emonds, O.R.P., Sechrest, W., Orme, C.D.L., Purvis, A., 2005. Multiple causes of high extinction risk in large mammal species. *Science* 309, 1239–1241.
- Clubb, R., Mason, G., 2003. Captivity effects on wide-ranging carnivores. *Nature* 425, 473–474.
- Collen, B., Purvis, A., Gittleman, J.L., 2004. Biological correlates of description date in carnivores and primates. *Global Ecology and Biogeography* 13, 459–467.
- Davidson, A.D., Hamilton, M.J., Boyer, A.G., Brown, J.H., Ceballos, G., 2009. Multiple ecological pathways to extinction in mammals. *Proceedings of the National Academy of Sciences of the United States of America* 106, 10702–10705.
- Fisher, D.O., 2010. Trajectories from extinction: where are missing mammals rediscovered? *Global Ecology and Biogeography*. doi:10.1111/j.1466-8238.2010.00624.
- Fisher, D.O., Blomberg, S.P., 2011. Correlates of rediscovery and the detectability of extinction in mammals. *Proceedings of the Royal Society of London – Series B* 278, 1090–1097.
- Fisher, D.O., Owens, I.P.F., 2004. The comparative method in conservation biology. *Trends in Ecology and Evolution* 19, 391–398.
- Gimenez-Dixon, M., Stuart, S., 1993. Action plans for species conservation, an evaluation of their effectiveness. *Species, Journal of the Species Survival Commission* 20, 6–10.
- International Monetary Fund, 2010. *International Financial Statistics International Monetary Fund, Calculator Published by NASA, Washington, DC, 2010* <<http://cost.jsc.nasa.gov/inflateGDP.html>> (accessed 22nd November).
- Isaac, N.J.B., Cowlshaw, G., 2004. How species respond to multiple extinction threats. *Proceedings of the Royal Society of London – Series B* 271, 1135–1141.
- Joseph, L.N., Maloney, R.F., Possingham, H.P., 2009. Optimal allocation of resources among threatened species: a project prioritization protocol. *Conservation Biology* 23, 328–338.
- MacPhee, R.D.E., Flemming, C., 1999. Requiem aeternam: the last five hundred years of mammalian species extinctions. In: MacPhee, R.D.E. (Ed.), *Extinctions in Near-time*. Kluwer Academic/Plenum, New York, pp. 333–371 (database: <http://creo.amnh.org/>).
- Magin, C.D., Johnson, T.H., Groombridge, B., Jenkins, M., Smith, H., 1994. Species extinctions, endangerment and captive breeding. In: Olney, P.J.S., Mace, G.M., Feisner, A.T.C. (Eds.), *Creative Conservation: Interactive Management of Wild and Captive Populations*. Chapman and Hall, London, pp. 3–31.
- Marešová, J., Frynta, D., 2008. Noah's Ark is full of common species attractive to humans: the case of boid snakes in zoos. *Ecological Economics* 64, 554–558.
- Medellin, R.A., Soberon, J., 1999. Predictions of mammal diversity on four land masses. *Conservation Biology* 13, 143–149.
- Metrick, A., Weitzman, M.L., 1996. Patterns of behavior in endangered species preservation. *Land Economics* 7, 1–16.
- Mittermeier, R.A., de Macedo-Ruiz, H., Luscombe, B.A., Cassidy, J., 1977. Rediscovery and conservation of the Peruvian yellow-tailed woolly monkey (*Lagothrix flavicauda*). In: Prince Rainier, H.S.H., III of Monaco, Bourne, G.H. (Eds.), *Primate Conservation*. Academic Press, New York, pp. 95–115.
- Owens, I.P.F., Bennett, P.M., 2000. Ecological basis of extinction risk in birds: habitat loss versus human persecution and introduced predators. *Proceedings of the National Academy of Sciences of the United States of America* 97, 12144–12148.
- R Development Core Team, 2010. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria <<http://www.R-project.org>>.
- Reeder, D.M., Helgen, K.M., Wilson, D.E., 2007. Global trends and biases in new mammal species discoveries. *Occasional Papers Museum of Texas Tech University* 269, 1–35.
- Roberts, D.L., Elphick, C.S., Reed, J.M., 2010. Identifying anomalous reports of putatively extinct species and why it matters. *Conservation Biology* 24, 189–196.
- Rodrigues, A.S.L., 2006. Are global conservation efforts successful? *Science* 313, 1051–1052.
- Scott, J.M., Ramsey, F.L., Lammertink, M., Rosenberg, K.V., Rohrbaugh, R., Wiens, J.A., Reed, J.M., 2008. When is an “extinct” species really extinct. Gauging the search efforts for Hawaiian forest birds and the Ivory-billed Woodpecker. *Avian Conservation and Ecology* 3, 3.
- Shuker, K., 1993. *The Lost Ark: New and Rediscovered Animals of the 20th Century*. Harper Collins, London.
- Sitas, N., Baillie, J.E.M., Isaac, N.J.B., 2009. What are we saving? Developing a standardized approach for conservation action. *Animal Conservation* 12, 231–237.
- Sutherland, W.J., 2003. *Ecological Census Techniques*. Cambridge University Press, Cambridge, UK.
- Ward, P.I., Mosberger, N., Kistler, C., Fischer, O., 1998. The relationship between popularity and body size in zoo animals. *Conservation Biology* 12, 1408–1411.